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PREFACE

Use of wheeled aircraft on the Greenland Ice Cap, particularly for support of Camp Century, may present certain advantages in view of the difficulties encountered with skis on the "Caribou" type aircraft during 1962.

During June, July, August, and September, when the support requirements of Camp Century are quite heavy, between 60 and 70% of the time is suitable for flying. A snow runway capable of supporting wheel landings with lightweight aircraft would be required. The construction of such a runway appears to be within the capability of the U. S. Army Polar Research and Development Center, with U. S. Army Cold Regions Research and Engineering Laboratory providing technical assistance.

The following discussion describes briefly the type of runway required, the method of construction, the effort involved, and suggested maintenance of the runway.

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Required supporting capacity of the snow runway

The specifications of a typical lightweight aircraft, the "Caribou", are:

Load per wheel (main gear)	6,108 lb
Load per wheel (nose gear)	2,036 lb
Tire contact area (main gear)	174.5 in.^{2}
Tire contact area (nose gear)	53.5 in.^{2}

Therefore:

Average contact pressure (main gear)	35 psi
Average contact pressure (nose gear)	38 psi

At design loads the average contact pressures are approximately equal to the recommended tire inflation pressures.

In order to support wheel loads producing contact pressures between 35 to 40 psi, the following ram hardness values are required for the top 6 in. of the snow pavement:

For:	1 coverage	120
	2 coverages	180
	4 coverages	260
	8 coverages	370
	20 coverages	460

(Each "coverage" indicates a wheel load passage in the same track.)

The above ram hardness values are reliable only if:

a) ram hardness for the 6 to 12 in. depth = 75% of the surface (0 to 6 in.) hardness;

b) ram hardness for the 12 to 18 in. depth = 50% of the surface hardness.

The minimum surface ram hardness required to support the "Caribou" is 120. This hardness can be obtained by rolling with corrugated or sheepsfoot rollers or compacting with LGP* tractors.

It would be unreasonable to assume, however, that the aircraft will never land in the same tracks. After numerous landings, the probability of a repeated landing on any previous wheel track is increased. Therefore, the 1-coverage criterion may not be realistic. It can also be assumed that contact pressures higher than 35 to 38 psi may be produced by impact during a landing. A 200 to 300 ram hardness range should, therefore, be considered as the minimum required.

Introducing a reasonable safety factor (approx. 1.5), a ram hardness of 300 at any point on the surface of the runway would be required.

In order to obtain a consistent hardness of this magnitude over the entire area of the runway and to decrease the possibility of dangerous soft spots, processing of the surface (3 to 4 ft depth) becomes necessary.

Method of constructing the snow runway

The preferred location of the runway would be on the existing runway at Camp Century.

A Peter plow, preferably 2 plows with backcasting chutes, would be used for processing a 3- to 4-ft thick surface snow layer. Rough leveling with an LGP tractor with

* Low ground pressure

blade and subsequent fine leveling with either the Gurries Road Builder (if available) or the Gurries Snow Planer (presently at Camp Century) or both would have to be performed immediately after processing (less than 4 hours after processing).

Approximately 1 week of age hardening would be required before the runway could be considered safe for landing the aircraft on wheels.

The natural surface snow density at Camp Century is approximately one-half of the density of Peter-plow processed snow. Therefore, a 4-ft deep cut would give only a 2-ft thick processed-snow layer. It would be very desirable to precompact the proposed runway area in order to increase the density of the snow layer to be processed. During the winter and early spring of 1963, this area could be compacted with LGP tractors and rollers after each significant snowfall. By doing this, it may be possible to obtain a 3-ft processed snow layer and so decrease the amount of depression of the runway in respect to the surrounding area. This would decrease the subsequent maintenance effort required for the compaction of accumulated snow on the runway.

It is realized that an elevated runway would be more desirable. However, the result may not be worth the considerable effort involved. An enormous amount of snow would have to be moved. Since the runway is oriented in the direction of the prevailing winds, the use of snow fences for snow accumulation would be of little help.

Testing of the runway

Periodic ram hardness tests of the processed snow runway should be performed during the initial age hardening period as well as during the use of the runway. It may also be desirable to use the 5-ton truck at Camp Century as a test vehicle to detect any soft areas which may have developed on the runway.

The first landing with the aircraft should be made on skis. Then the plane should taxi on wheels over the entire length of the runway. If there are no indications of unsafe conditions, take-offs and landings on wheels can follow.

Estimate of the required effort and time for runway construction

The most desirable time for the runway construction would be the first weeks in June. At this time the Gurries Road Builder may be available. Also, the weather conditions during June are such that reasonable efficiency and production can be expected. It is very important that the leveling operation be performed within a few hours after the processing. Frequent delays due to unfavorable weather may severely hamper the proper sequence of operations, and impair the quality of the completed runway as a whole.

Assuming a 5000 x 150 ft runway and a 3 to 4 ft deep cut, the approximate construction time required could be estimated as follows:

Rate of cut = 10 ft/min = 600 ft/hr
Time per cut = 5000 ft @ 600 ft/hr = 8.33 hr ≅ 8.5 hr/cut
Number of cuts = 150 ft @ 8 ft/cut = 18.75 cuts ≅ 20 cuts
Actual cut time = 20 cuts x 8.5 hr/cut = 170 hr
Machine time = cut time x 1.5 = 255 hr

Assuming a two-shift, 10 hr each, operation:

255 hr @ 20 hr/day = 12.75 days ≅ 13 days

Assuming 2 plows:

Total time = 6.5 days.

Assuming 2 days/week lost due to bad weather:

Total time = 8.5 days (2 Peter plows).

Using a safety factor of 1.5 for maintenance and minor mechanical difficulties:

Total time ≅ 13 days (with 2 Peter plows).

Therefore, the runway could be constructed in 2 weeks, using two Peter plows, and taking into consideration delays due to weather, maintenance, and minor mechanical difficulties.

An LGP tractor with blade would be required for rough leveling and towing of the Gurries Planer or Road Builder.

Maintenance of the runway

Because of the somewhat depressed nature of the runway, some snow accumulation, primarily due to drifting, can be expected on the runway during the summer months. Since this would usually be a matter of a few inches accumulation at a time, compaction with an LGP tractor may be sufficient to maintain the required surface hardness. Leveling with the Gurries Road Builder or the Snow Planer immediately after compaction will provide a smooth surface. It would be necessary then to allow this newly compacted and leveled snow layer to age harden at least 48 hours. Ram hardness tests and traffic tests with the 5-ton truck will indicate whether or not a wheeled aircraft landing would be safe.

Compaction of a few inches of snow accumulation on top of the hard, processed snow pavement would be less time-consuming than removal of the snow. More important, the elevation of the runway would be maintained at a level comparable to that of the surrounding area. Also, by attempting to remove a few inches of snow, the original surface of the runway may be damaged.

Removal of a new snow accumulation is not recommended at any time. This would only create more problems later. After a heavy new snow accumulation, 8 to 12 inches, for example, it may be difficult to attain the required ram hardness. This is possible, nevertheless, by repeated compaction coverages with an LGP. This situation will be encountered during the early spring and late fall periods when the snow accumulation is the heaviest.

It is very important, therefore, that new snow accumulation and drifts be compacted and leveled whenever necessary. If periodic compacting of new snow can be maintained throughout the year, it may be possible to have the runway operational on a year-round basis. If, however, snow is allowed to accumulate during the less active winter season without periodic compaction, it may be necessary to process the full depth of the new snow during the next spring.

Compaction with LGP tractor tracks is superior to compaction by any other means.

During July and August, temperatures at Camp Century occasionally reach or exceed 32F, and softening of the top few inches of snow may become dangerous for wheel landings. Since temperatures in this range usually do not last more than a few hours, freezing of the soft surface will follow with even a possible increase in the surface hardness.

During the summer of 1962, the temperature rose to 32F only twice. Softening of the runway surface can occur during bright, sunny days, even though the air temperature may be below 32F. There is little that can be done to keep the runway surface hard during the hours of apparent melting.

During periods of warm weather, it may be necessary to take advantage of the cooler early morning hours for safe landings on wheels.

It is important that oil or fuel spots on the runway surface be removed or covered with snow. When exposed to sun, the dirty spots may create dangerous pot holes.

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APPENDIX A

USE OF THE RAMMSONDE HARDNESS INSTRUMENT FOR DETERMINING THE SUPPORTING CAPACITY OF A SNOW RUNWAY

The Rammsonde hardness instrument consists of a hollow aluminum shaft with a 60° conical tip, a guide rod, and a drop hammer. The guide rod, inserted into the top of the shaft, guides the drop hammer. The hammer is raised by hand to a certain height, which is read in cm on the guide rod, and then dropped freely. The number of hammer drops (or blows) required to obtain a certain penetration is determined. The depth of penetration is read from the centimeter scale on the shaft. The widest part of the cone is 3.5 cm from the tip, and the total length of the penetrometer cone element (to the beginning of the shaft) is 10 cm.

The ram hardness is computed from the following expression:

$$R = \frac{Whn}{s} + W + Q$$

where:

R = ram hardness number

W = weight of hammer (kg)

h = height of drop (cm)

n = number of blows

s = penetration after n drops (cm)

Q = weight of penetrometer (kg)

The weight of the penetrometer (Q) is approximately 1 kg. For determining the ram hardness of a snow runway, the 3-kg drop hammer is usually used (W = 3 kg), and the number of blows (n) is determined for each 5-cm penetration increment (s = 5 cm). A 20-cm drop height (h) is used until a 15 or 20 cm penetration is reached. After that, a 50-cm drop height can be used, if more than 10 blows are required to obtain a 5-cm penetration from a 20-cm drop height.

The expression then becomes:

$$R = \frac{3hn}{5} + 4$$

where: h = either 20 or 50

therefore:

$$R_{(h=20)} = 12\,n + 4$$

$$R_{(h=50)} = 30\,n + 4$$

Because of the conical shape of the penetrometer and the vicinity of a free surface, the hardness number (obtained by the above expressions) has to be multiplied by 4.7 for the 0 to 5 cm penetration and by 1.6 for the 5 to 10 cm penetration to obtain the true ram hardness of the 10-cm surface layer.

The number of ram hardness tests required and the distance between them depends on the results of the first several tests. For example, if the first 10 or 20 ram tests, taken at random locations in the area where the aircraft is expected to land and take off, show the runway to be considerably harder than required, further testing would primarily be needed to locate any areas that may not have the required hardness. If, however, the initial indications are that the runway hardness conditions are marginal, extensive further testing would be required.

The required ram hardness profiles (the minimum for supporting the indicated wheel load, minimum safe condition, and recommended design) are shown on Figure A1. Because the highest hardness in a processed, compacted snow pavement usually occurs at some depth below the surface (4 or 5 inches) instead of at the surface, the shapes of the curves shown represent the type of hardness profiles that would most likely be found in a snow pavement. The ideal profile would, of course, have the maximum hardness at the surface of the pavement.

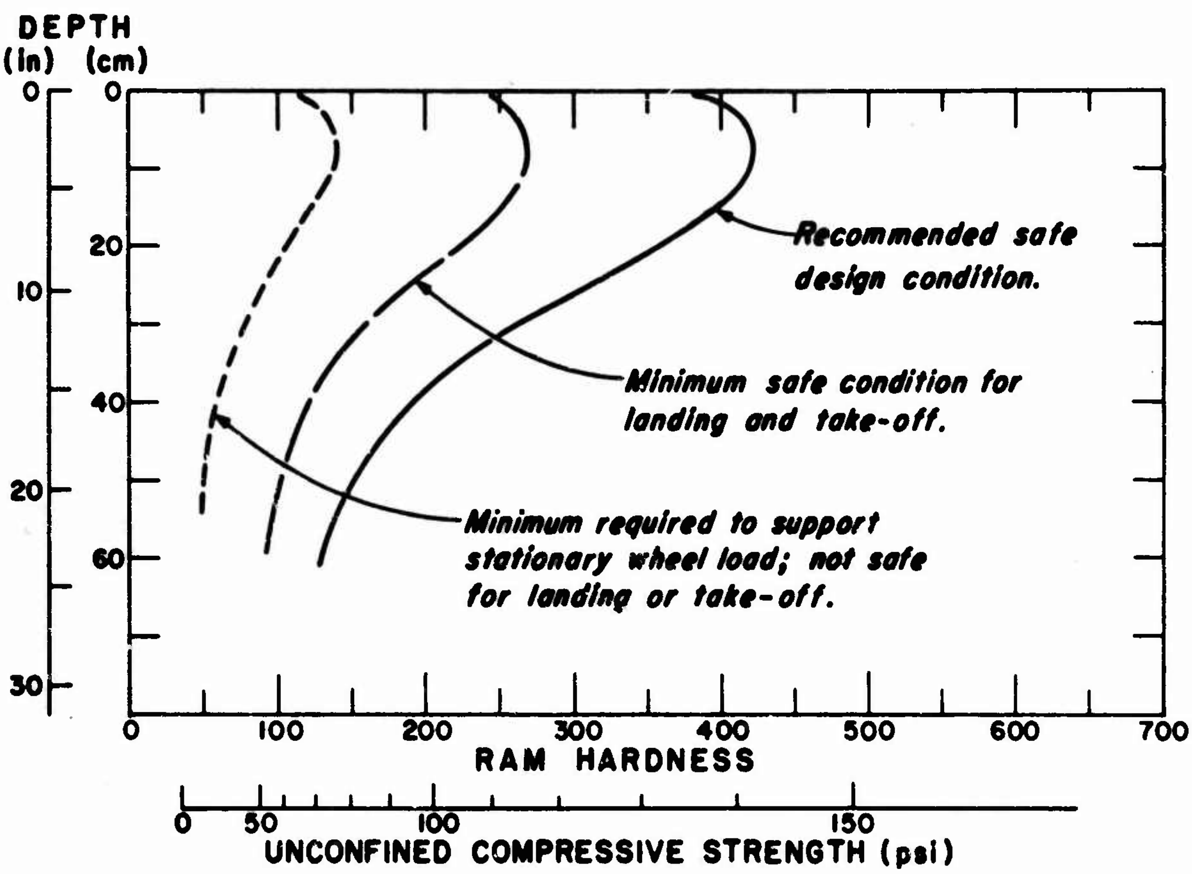

Figure A1. Required ram hardness profiles for supporting aircraft wheel loads of 6000 lb and producing average contact pressures up to 40 psi.